

The LANL/LLE Gated Monochromatic X-ray Imager (GMXI) for the Omega Laser Facility

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Some of the most important diagnostics used in the ICF program are gated x-ray imagers. These imagers can resolve broadband x-rays, (1 - 8 keV) both temporally (80 ps) and spatially (20 lp/mm). What sets the Gated Monochromatic X-ray Imager (GMXI) apart from current technology is the ability to maintain resolution, temporally and spatially, while observing a very narrow band of x-rays on the order of 10 to 20 eV. The diagnostic is designed to easily change between different energy ranges of interest by simply rotating a Bragg crystal. This technique is important because it isolates line emission from a single element and improves signal to noise ratios by rejecting continuum or background radiation.

This new gated monochromatic imaging system is a product of a successful collaboration between University of Rochester's Laboratory for Laser Energetics and Los Alamos National Laboratory. We collectively have designed, developed, and tested the imaging system at both LANL's Trident laser and LLE's Omega Upgrade. This new imaging system is an significant diagnostic for Omega yielding critical information concerning target symmetry, size and density of ICF implosions.

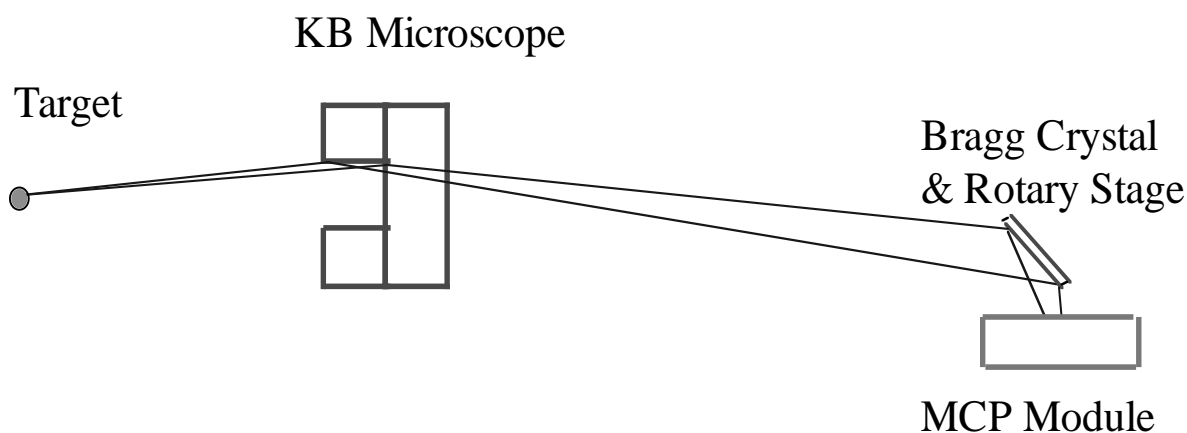


Fig. 1. Layout of the gated monochromatic imaging system.

Figure 1 shows a layout of the GMXI system consisting of a grazing incidence KB microscope which is arranged to form 4 images. Near the focal point, the 4 beams illuminate 4 separate Bragg crystals. The crystals are mounted upon two crystal turrets (left and right), which can rotate through $>45^\circ$ (θ) on computer controlled rotary stages. The diffracted image finally falls upon a pair of gated microchannel plates (MCP) modules

which can rotate through 90° (2θ). The KB mirrors are designed to sit on the target-chamber-center side of a vacuum flight tube protected by a Beryllium debris shield. On the other end of the vacuum tube is a square vacuum tank which houses the crystals, rotary stages, and MCP modules.

The KB microscope design consists of two pairs of cylindrical mirrors arranged perpendicularly to each other to produce four images. Typical parameters of the KB microscope are: mirror radius = 28 m, angle of incidence = 0.7° , magnification = 14, and solid angle = 4×10^{-7} sr. Tests performed at LANL's Trident laser facility and with DC x-ray sources have shown the best resolution to be $\sim 5 \mu\text{m}$ with a depth to field in excess of 1 mm. To enhance reflectivity of the KB mirrors we have tested various metallic coatings. Previous KB mirrors have been Au-coated with reflectivity measured using a DC x-ray source. Present KB mirrors are Ir-coated, resulting in relatively increased reflectivity for higher photon energies (8 kV) as compared to Au.

The light from the KB microscope is made monochromatic by placing a Bragg crystal just before the focal plane of the KB. Typical crystals for this application are LiF ($2d = 4.027 \text{ \AA}$) and Highly Oriented Pyrolytic Graphite (HPOG) ($2d = 6.708 \text{ \AA}$). The crystal is placed at an angle θ relative to the incident x-rays and the gating module is placed at an angle of 2θ . The wavelength (λ) of the diffracted x-rays is given by the Bragg equation, $2d \sin \theta = n\lambda$, where d is the crystal plane spacing and n is the diffraction order. Since the crystal has a finite angular response to wavelength λ , this yields a finite field of view Δx given by $\Delta x = s\Delta\theta$, where $\Delta\theta$ is the width of the crystal rocking curve and s is the distance from source to mirror. Typical values for $\Delta x = 700 \mu\text{m}$ with crystal rocking curves of $\Delta\theta = 0.2^\circ$ (LiF). For an x-ray source emitting broadband radiation, the effective energy band ΔE is given by $\Delta E = E \cot \theta \Delta\theta$. Crystal reflectivity's (R_p) have been measured at $R_p = 0.15$ for LiF and $R_p = 0.27$ for HPOG.

The crystal turrets sit upon two separate computer-controlled rotary stages with 1 arc second resolution. The rotary stages drive a pair of vertical shafts. The crystal is set at an angle of θ , relative to the incident radiation, while the MCP module is set at an angle of 2θ . The usable range of crystal angle is between $\theta = 0^\circ$ to 50° .

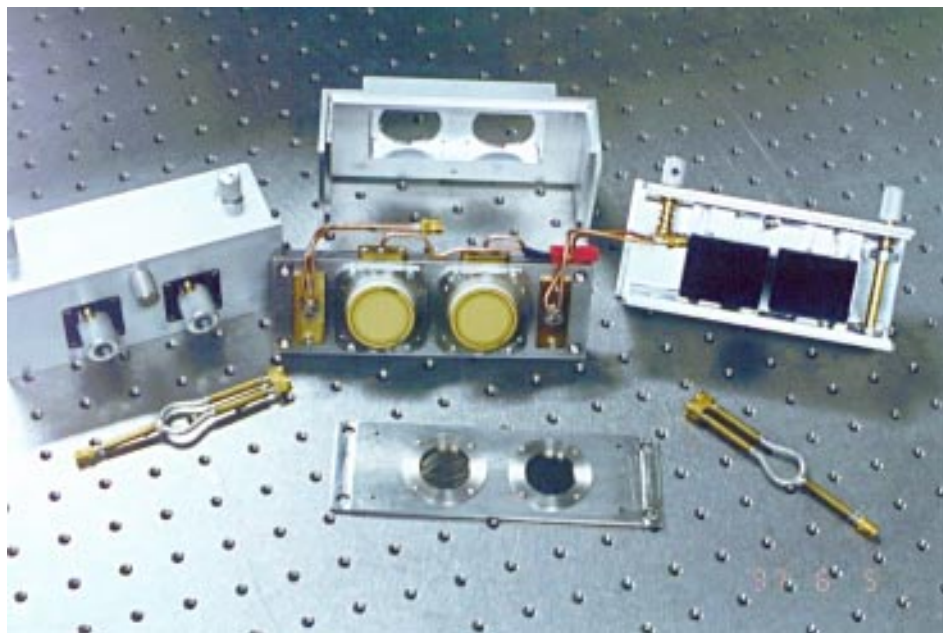


Fig. 2. MCP module and film packs designed by Los Alamos.

The four monochromatic images formed by the microscope and crystals are arranged in a square pattern with 53 mm sides at the image plane. Each image falls on its own 25 mm diameter MCP, which is proximity focused to a fiberoptic faceplate coated with P-11 phosphor. The MCPs have a micropore length over diameter of 40 ($L/D=40$) and the fiberoptic faceplates have 6 μm diameter fibers. The MCP and phosphor screen separation is 500 μm and typically has a bias of 3 kV. Light from the P-11 phosphor is recorded by Kodak 2484 film loaded into a film cassette that is compressed against the fiberoptic faceplate with a film plunger. As shown in Figure 2, each module contains a pair of 25 mm MCPs, with centers separated by 53 mm. Each MCP has an 8 ohm microstrip, 10.2 mm wide, which acts as the electrical conduit for the gating pulse and the photocathode. The microstrip is constructed of 5000 \AA Cu overlaid by 1000 \AA of Au and 50 \AA of Chromium. The MCPs are fed by conical impedance matching transmission lines and microstrip ohmic tapers. These devices efficiently transfer the MCP gating voltage pulse from 50 ohms to 8 ohms and back out again to a pulse monitor and DC biasing. To gate the x-rays, a short duration, high voltage pulse travels across the MCP stripline with a propagation velocity of 0.5 c. Photo-electrons from the Au photocathode are amplified only during the pulse duration at a given point along the microstrip. The LANL built gating pulsers have an amplitude of 4 kV and an electrical width of 150 ps FWHM. These avalanche transistor based pulsers give us an ~ 80 ps optical gate with MCPs having micropore length over diameters of 40 ($L/D = 40$). The optical gate width of this system was measured with an ultra-short pulsewidth UV laser.

Recent full system characterization tests at Omega have qualified both KB optic and gating modules for routine use as shown by Figure 3 below.

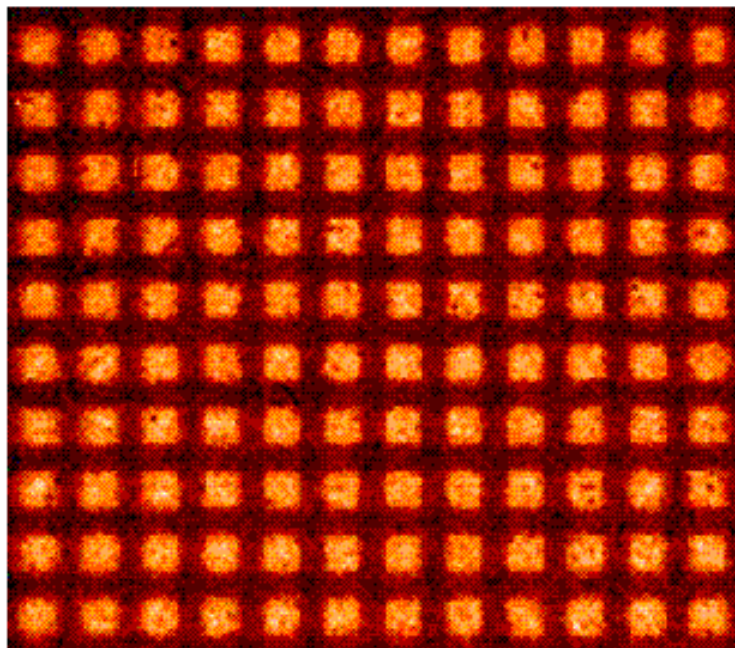


Fig. 3. Backlit 500 mesh grid images with the GMXL.